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Summary

A series of flight tests were conducted to evaluate the reduction of takeoff ground roll distance obtainable from a rapid extension of the nose gear strut. The NASA Quiet Short-haul Research Aircraft (QSRA) used for this investigation is a transport-size short takeoff and landing (STOL) research vehicle with a slightly swept wing that employs the upper surface blowing (USB) concept to attain the high lift levels required for its low-speed, short-field performance. Minor modifications to the conventional nose gear assembly and the addition of a high-pressure pneumatic system and a control system provided the extendable nose gear, or jump strut, capability. The limited flight test program explored the effects of thrust-to-weight ratio, wing loading, storage tank initial pressure, and control valve open time duration on the ground roll distance. The data show that a reduction of takeoff ground roll on the order of 10% was achieved with the use of the jump strut as predicted. Takeoff performance with the jump strut was also found to be essentially independent of the pneumatic supply pressure and was only slightly affected by control valve open time within the range of the parameters examined.

Introduction

The minimum takeoff ground roll distance of conventional- and short-takeoff aircraft is influenced by (among other factors) the horizontal tail's effectiveness in rotating to a liftoff pitch attitude at the minimum controllable airspeed. For some configurations, particularly high thrust-line types, the pitch-up tail moment commanded by the pilot is countered by the moment due to engine thrust.

Beginning in 1982, the Flight Dynamic Laboratory of the U.S. Air Force Wright Laboratory investigated a possible approach for reducing the ground roll which involved the use of a pneumatically extendable nose gear, referred to as the jump strut. This joint industry/Department of Defense effort resulted in the development of an F-16 jump strut nose gear which was ground tested at Wright Laboratory. In 1985, a T-38 aircraft with a nose gear jump strut was ground-run tested at the Naval Air Test Center, Patuxent River, Maryland. This test provided a database for a subsequent analytical simulation which predicted that a substantial reduction of the takeoff distance of tactical aircraft could be obtained (ref. 1). Wright Laboratory also participated in the Advanced Transport Technology Mission Analysis assessment studies (ref. 2) which showed that the nose wheel jump strut, when used as a rotational aid, produced a significant improvement in takeoff performance for some of the transport aircraft configurations evaluated.

In 1987 a study by Lockheed, Burbank (ref. 3), funded jointly by Wright Laboratory and NASA Ames Research Center, investigated the takeoff benefits of the jump strut applied to the NASA Quiet Short-haul Research Aircraft (QSRA) and concluded that, at a thrust to weight ratio of 0.4, reductions of 10–12% of takeoff distance were possible with a two-stage pneumatic jump strut. The QSRA (fig. 1) is a slightly swept high-wing transport-size short takeoff and landing (STOL) research vehicle that employs

Figure 1. QSRA in the takeoff configuration.

*U.S. Air Force Wright Laboratory, Wright-Patterson AFB, Ohio.

**Menasco Aerosystems Division, Fort Worth, Texas.

upper surface blowing (USB) to achieve unusually high lift levels for its low speed capabilities and short-field takeoff and landing performance (ref. 4). The demonstrated low-speed stability of the QSRA makes it an excellent flight test facility to explore the effect of the jump strut on STOL aircraft takeoff performance. Furthermore, the QSRA is an interesting choice for this investigation because the USB configuration presents an adverse nose-down pitching moment due to the high thrust line which diminishes the pitch-up rate during takeoff, thereby increasing the minimum liftoff speed. Authorization to proceed with the experiment was granted in 1989 upon the issuance of a NASA/U.S. Air Force Memorandum of Understanding (MOU) which defined the objective to flight-demonstrate a nose jump strut system on NASA's Quite Short-haul Research Aircraft.

The authors wish to thank the QSRA Flight Test Team for their assistance and suggestions in conducting this experiment. We are particularly indebted to the flight crew: Gordon Hardy, Project Pilot, Jim Martin and Bill Hindson, Test Pilots, the ground crew: Richard Young, Crew Chief, Dave Walton, Inspector, and John Lewis, Instrumentation Engineer, and to Benny Cheung, Electronic Systems Engineer.

Approach

Project management of the QSRA/jump strut investigation was assigned to Ames Research Center, Moffett Field, California. NASA provided: technical direction; contract monitoring; the QSRA aircraft; the engineering and technical staff and the operations infrastructure required for the development; and test of the flight hardware. The U.S. Air Force was responsible for technical coordination with NASA, contract funding, and landing gear assembly laboratory performance testing. The Air Force also shared in the costs of the flight test pressure reservoir, a pneumatic system, a control system, and the required instrumentation.

Modifications to the QSRA included replacing the original nose gear with a jump strut nose gear, installing a pressure reservoir, a pneumatic system, a jump strut control system, and the required instumentation.

A non-serviceable QSRA nose gear was restored to flightworthy condition and modified by Menasco Industries to provide the pneumatic extension, capability. The reworked nose gear represented a low cost, low complexity system which operates as a normal nose gear after its use during takeoff. Preliminary functional tests were performed by Menasco and gear validation tests were conducted at Wright Laboratory.

After installation of the jump strut system on the QSRA, a series of static tests was conducted to verify the performance of the electrical and pneumatic systems and to calibrate the new instrumentation. Following these static tests, the flight program was initiated. The first phase of flight testing performed at NAS Moffett Field, California, focused on operational (piloting) techniques. The subsequent data-flight tests were conducted at NALF Crows Landing, California.

Test Objectives

The primary goal of this program was to experimentally determine the effect of using a nose gear jump strut on takeoff ground roll distance. Associated with this overall objective the following specific objectives were targeted:

Determine the influence of jump strut parameters (initial pneumatic reservoir pressure and valve-open time) on takeoff ground roll distance.

Determine the influence of thrust to weight ratio on ground roll distance with and without jump strut assistance.

Experimentally verify analytical predictions of the reduction of takeoff ground roll distances.

Evaluate jump strut system performance, loads, and service operations.

Determine the repeatability of takeoff ground roll distance.

Identify areas for further study.

Instrumentation

The instrumentation installed in the QSRA was developed specifically to document the aircraft state, operating conditions, and control positions and forces for flight investigations in the terminal area flight regime. Several parameters were added to the existing QSRA instrumentation list to satisfy the requirements of this project.

Data from the transducers are transmitted to a remote multiplexer/digitizer unit (RMDU) which provides signal conditioning for the transducer, converts the analog data to digital form and encodes the data into a pulse code modulation (PCM) serial bit stream. Approximately 130 QSRA parameters are sampled at 100 samples/second and an additional 18 parameters are acquired at 20 samples/second. The PCM bit stream is recorded on an on-board tape recorder and telemetered to the ground data monitoring station. The telemetered signal is also recorded on the ground. The ground recording includes

ground-based data such as aircraft tracking position and ambient (atmospheric) conditions. Selected parameters are displayed in engineering units in real time in the ground station to enable safety and programmatic monitoring. The formats used included time histories ("strip charts"), digital displays, and x-y plots. Laser and radar tracking data was acquired from the existing Crows Landing NASA test range equipment.

Vehicle/System Description

Aircraft

The QSRA (fig. 2) was first flown by NASA Ames Research Center in 1978 as a research aircraft to investigate propulsive lift and to demonstrate, simultaneously, the low noise benefit obtained by placing the engines over the wings. These dual purposes complimented each other in that the over-the-wing engine exhaust flow experiences the Coanda effect, thereby producing the high lift effectiveness due to exhaust flow deflection and supercirculation (ref. 4). This configuration is referred to as upper surface blowing (USB).

The QSRA has been performing STOL flight research at Ames Research Center since 1978. These prior flights provided the low speed performance and flying quality data that supported the use of the QSRA for the jump strut evaluation.

The QSRA consists of a deHavilland C-8A Buffalo fuselage and empennage with a modified wing/propulsion system designed and fabricated by Boeing. The high T-tail on the C-8A Buffalo was modified to include fully powered elevator operation. The four YF-102 AVCO Lycoming fan jet engines, which are capable of producing approximately 6,000 lb of thrust each, are mounted above the wing in acoustically treated nacelles. Neither the main nor nose landing gear are retractable.

Jump Strut System

The jump strut system can be divided into three elements, as illustrated in figure 3

The jump strut nose gear,

The pneumatic system, and

The electronic control system.

AERODYNAMIC DATA

	WING	HORIZ	VERT
AREA (TRAP), ft^2	600.00	233.00	152.00
SPAN, ft	73.50	32.00	14.00
ASPECT RATIO	9.00	4.40	1.22
TAPER RATIO	0.30	0.75	0.80
SWEEP, C4, deg	15.00	3.00	18.00
M.A.C. in.	107.40	88.00	137.00
CHORD ROOT, in.	150.70	100.00	168.00
CHORD TIP, in.	45.20	75.00	100.00
T/C BODY SIDE, %	18.64	14.00	14.00
T/C TIP, %	15.12	12.00	14.00
INCIDENCE, deg	4.50	–	–
DIHEDRAL, deg	0.00	–	–
TAIL ARM, in.	–	525.0 in.	488.0 in.
VOL COEFF V	–	1.898	0.1402

CONTROL SURFACES

ft^2/APL*		BLOWN
AILERON	32.2	BLC
FLAPS INBD	105.0	USB
FLAPS OUTBD	40.2	NONE
SPOILERS	33.7	NONE
L.E. FLAPS	64.3	NONE
ELEVATOR	81.6	NONE
RUDDER	60.8	NONE

*THEORETICAL RETRACTED AREA

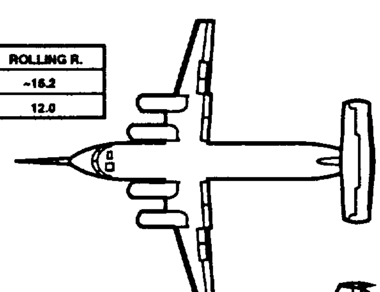
PROPULSION

ENGINE	LYCOMING YF-102
STATIC THRUST	6225**
FAN P.R.	1.45
BY-PASS RATIO	6.00

**MEASURED THRUST

LANDING GEAR

GEAR	STROKE	TIRE	TIRE O.D.	ROLLING R.
MLG, in.	21.0	14 x 16	37.0	~16.2
NLG, in.	17.5	8.90-12.50 TYPE III	27.5	12.0



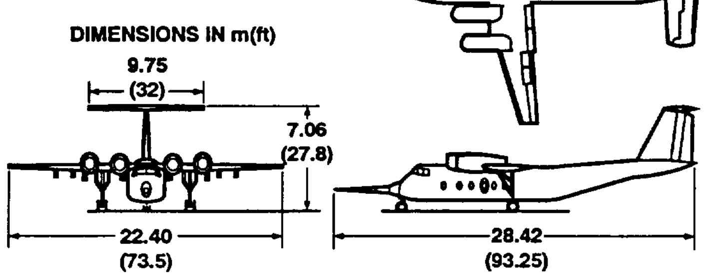


Figure 2. Quiet Short-haul Research Aircraft configuration and dimension details (from ref. 4).

Nose gear and strut– The original QSRA nose landing gear assembly is a two-stage device which has both high and low pressure air chambers. The gear features both air and oil to provide shock absorbing and rebound damping during all aircraft ground operations. Figure 4 shows the original nose landing gear prior to modification. The rate of the strut movement is controlled by regulating oil flow through the oil metering device comprising the piston head, flapper and metering pin.

A non-serviceable QSRA nose gear/strut was reconditioned and modified to provide a movable "jump piston" (fig. 5). The metering pin is attached to the added jump

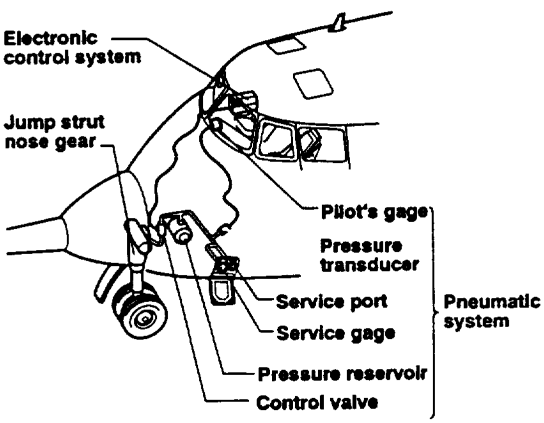


Figure 3. Jump strut Original QSRA nose gear.

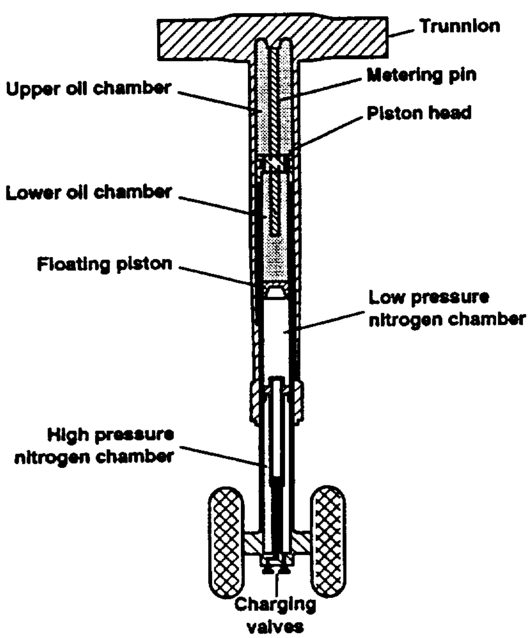


Figure 4. Original QSRA nose gear.

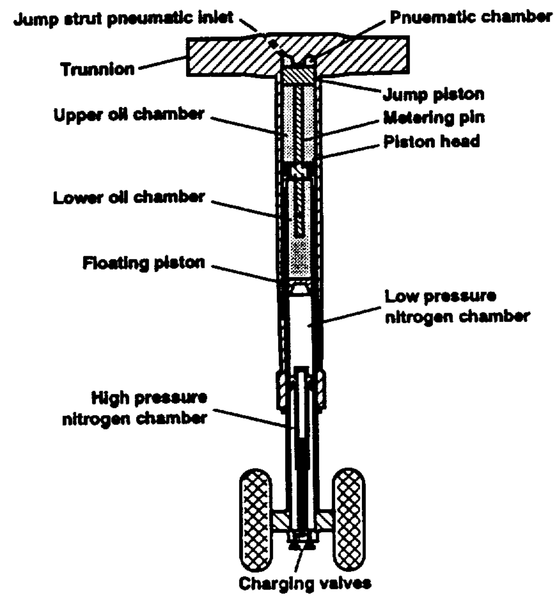


Figure 5. Jump strut nose gear.

piston instead of the trunnion. A hole was drilled through the trunnion to enable the injection of high pressure gas into the chamber above the jump piston.

In the jump strut mode, the application of high pressure gas to the upper chamber extends the strut, and the subsequent reaction forces from the runway cause the nose of the aircraft to lift.

Pneumatic System

Figure 6 shows the jump strut pneumatic system. The main components are storage tank (pneumatic reservoir),

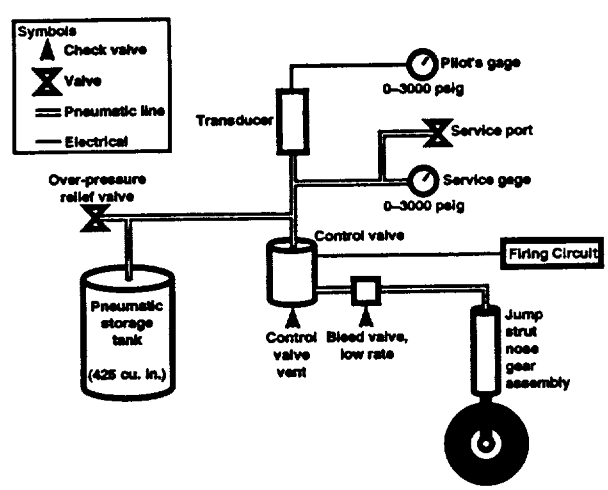


Figure 6. Jump strut pneumatic system.

control valve, safety valves and gages. Briefly, the operation is as follows:

The storage tank is charged to the desired pressure through a service port located on the port side of the aircraft. A separate pressure gage is provided for both the flight- and ground-crews. The required equipment was both small and light, which enabled the storage tank and control valve to be located in the nose wheel well. The storage tank weighs 20 lb, has a volume of 425 cu. in. and a maximum operating pressure of 3,000 psig. The relief valve, set to open at 3,500 psig, protects against over pressurization, while the vent on the electrically activated control valve exhausts the supply lines to atmospheric pressure when the valve is not supplying high-pressure gas to the upper cylinder. The bleed valve in the system provides an escape for the high pressure gas so that the pressure in the upper chamber reduces to atmospheric level within seconds after jump strut operation, thereby returning the nose gear to its conventional state.

Jump Strut Control System

The electronic control system contains the arming and timing circuits (fig. 7). Operation of the jump strut requires the firing system to be armed prior to triggering the control valve. The timing circuit enables the duration of the valve-opening to be set during the flight investigation within the range of 3 to 170 msec. The firing system circuit is completed through the nose gear-on-ground (squat) switch, thus the circuit can only be energized when the nose gear is compressed (structural limitations prohibit operating the jump strut with the nose wheel off the ground). Dual firing circuits are provided for safety reasons. If the first timing circuit fails in the "valve-open" mode, the second circuit will limit the duration of the valve-opening. For these tests, the backup timing circuit was set at the maximum firing time (170 msec).

The arm/disarm circuit protects against inadvertent firing as long as the arm switch is not engaged. Also, after the system is triggered, the circuit is automatically disarmed to avoid an accidental second firing. The firing button was placed on the number-one power lever and the arming and timing controls were placed on the starboard side in the co-pilot's control area.

Wright Laboratory Ground Qualification Tests

The modified QSRA nose strut was functionally tested at the manufacturer's plant. The contractor evaluations consisted of verifying conformance with drawings and specifications, and conducting pressure leakage and jump piston operation tests. Functional acceptance tests were performed at Wright Laboratory using the test set up shown in figure 8.

The testing conducted at Wright Laboratory included documentation of load-stroke curve, drop test, static jump tests, and dynamic jump tests.

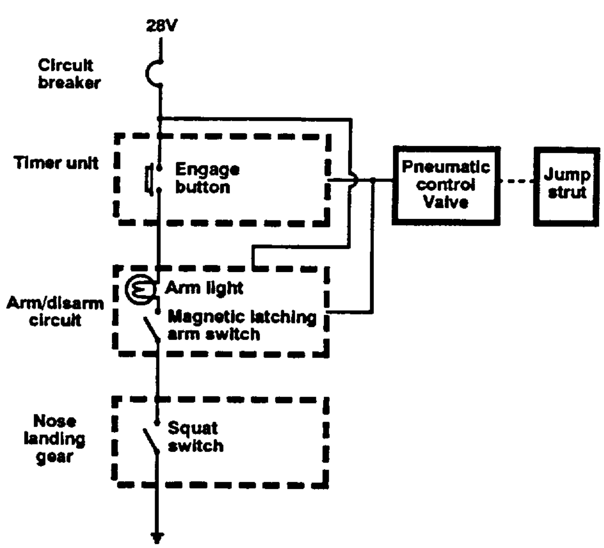


Figure 7. Jump strut electronic system.

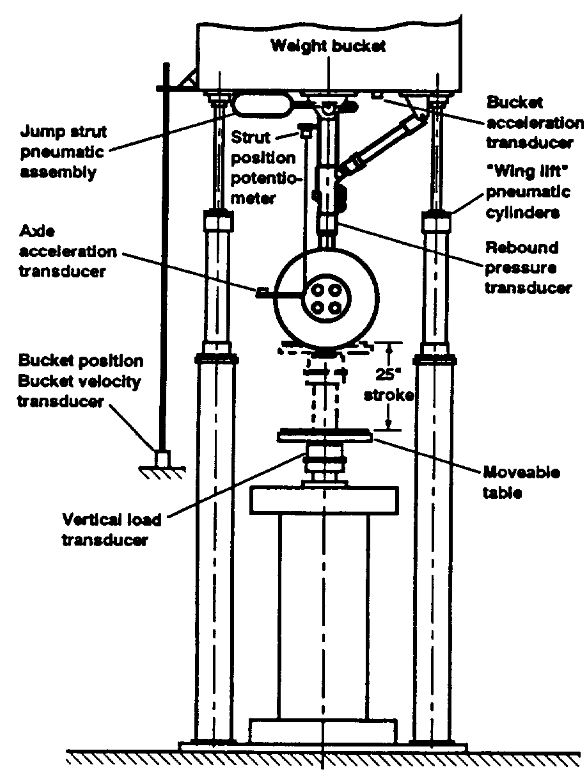


Figure 8. Wright Laboratory landing gear test stand.

The load stroke curve was generated by locking the landing gear trunnion in place and using the stroke of the base (moveable table) to compress the strut. The first loading provided an adiabatic compression and release of the strut in two seconds. The second test compressed and released the strut in 100 sec, yielding an isothermal loading.

The results shown in figure 9(a) duplicated the original specifications of the manufacturer (Menasco) for the two stage nose wheel strut thereby conforming to the requirement that the performance of the modified strut match that of the original configuration.

The drop test called for a 12 foot-per-second sink rate (the original nose strut specification) with a nose weight of 4,788 lb. The weight on the nose is based on a QSRA gross weight of 48,000 lb and a center of gravity located at 25% of MAC. The drop test utilized the minimum available bucket weight of 6,700 lb and a reduced drop test distance to produce the appropriate impact load. Figure 9(b) shows the vertical forces as a function of the strut compression. The simulated operational loads did not exceed the aircraft and nose gear manufacture's operating structural limits.

The static jumps (fig. 9(c)) simulated a stationary aircraft with a gross weight of 55,000 lb and a center of gravity located at 26.5% of MAC. The jump strut was fired at various reservoir pressures (1,000 to 3,000 psig) and valve-open time intervals (50 to 130 msec). For these tests the pneumatic cylinders were used to produce an effective weight on the nose wheel of 5,815 lb. The compression and settling of the strut following the full extension, shown in figure 9(c), would not be experienced in an actual takeoff.

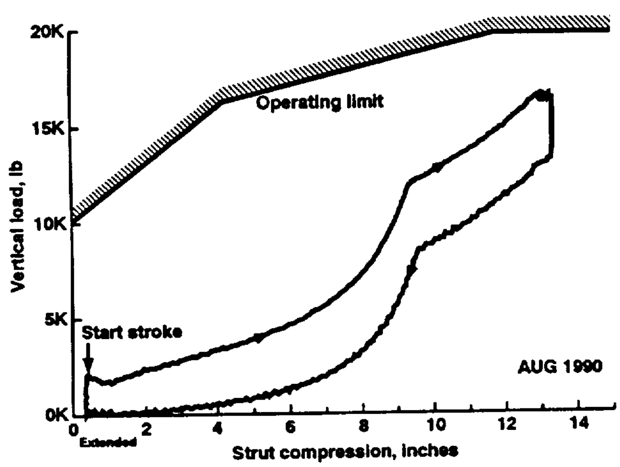


Figure 9. (a) Adiabatic load/stroke variation (Wright Laboratory).

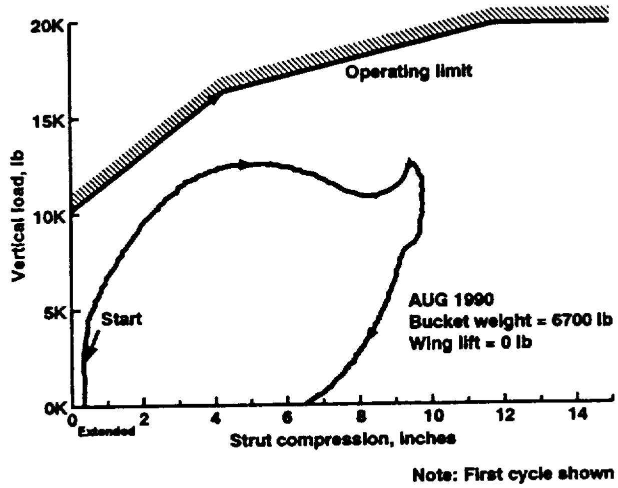


Figure 9. (b) Drop test load/stroke variation (Wright Laboratory).

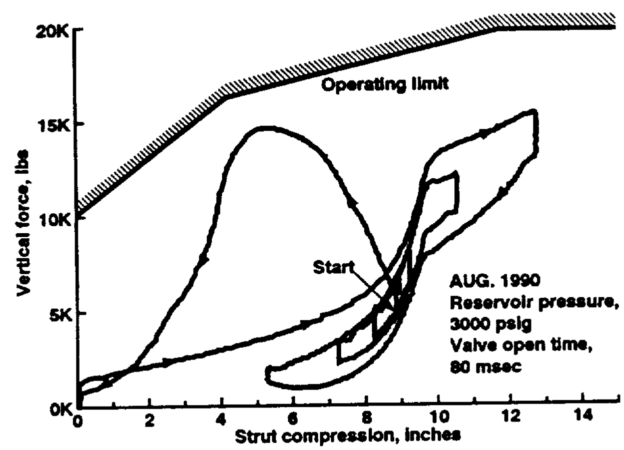


Figure 9. (c) Static jump load/stroke variation (Wright Laboratory).

The dynamic jump strut firings simulated a takeoff operation and were the same as the static jump tests except the effects of wing and tail lift were included, thereby reducing the weight on the nose wheel to about 4,600 lb. As in the static jumps, the pneumatic cylinders were used to obtain the desired nose wheel weight. The wing lift was calculated assuming a QSRA runway speed of 60 KIAS (the nominal velocity at start of rotation). Figure 9(d) shows that the extension and compression of the strut remained within operational limits. Again, as in the static jump, the compression due to the wheel re-contacting the ground after full extension would not occur during an actual takeoff.

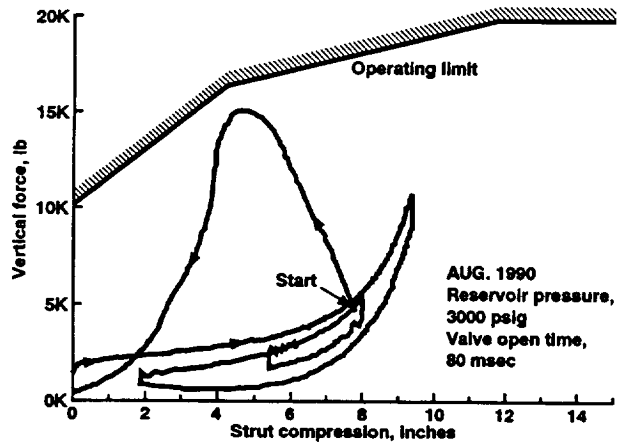


Figure 9. (d) Dynamic load/stroke variation (Wright Laboratory).

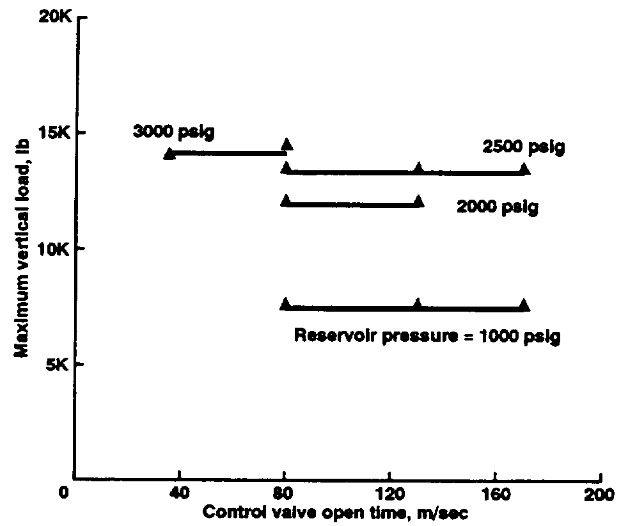


Figure 11. (a) Variation of maximum load with valve open time and reservoir pressure (Wright Laboratory).

Ames QSRA Static Jump Strut Tests

The instrumentation and the electronic fire control system were installed calibrated on the QSRA at Ames prior to jump strut test operations. The nose gear vertical load was determined by measuring the bending moment on the trunnion which was calibrated by placing the nose wheel on scales. The main wheels were elevated to level the aircraft. The QSRA static calibration arrangement as shown in figure 10. A broad range of nose gear vertical loads was obtained by varying the thrust of the engines. The summation of moments about the main gear provided a means of assessing engine thrust as a function of fan rpm. The results of this data analysis compared very well with prior engine static thrust calibration data.

Figure 11 shows the vertical nose gear maximum load versus the jump strut control valve-open time for both the Wright Laboratory tests and the QSRA static jump tests. Both sets of data show that the maximum load is essentially independent of valve-open time but increases with reservoir pressure. The maximum load obtained from the Wright Laboratory test was found to be about 10% greater than the QSRA test data. The source of this difference has not been identified. Figure 12 shows the effect of valve-open time on the load/stroke cycle. The larger time maintained higher loads for nearly the full extension of the strut, thereby approaching the structural limits of the system. It should be noted that the difference between the Wright Laboratory data (fig. 9(c)) and the QSRA data (fig. 12) in the stroke/load curve shape, during the extension of the strut after the peak load is reached, is primarily due to the differences in the load on the nose gear.

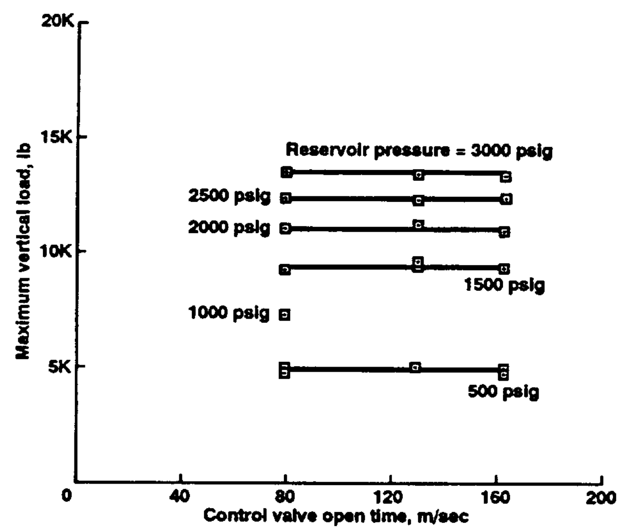


Figure 11. (b) Variation of maximum load with valve open time and reservoir pressure (QSRA).

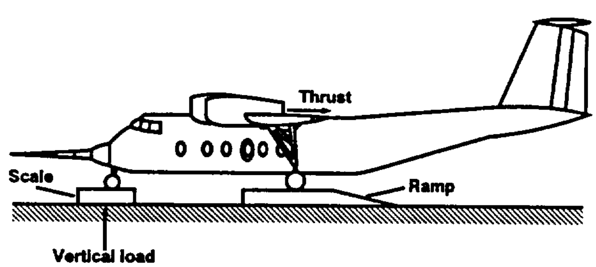


Figure 10. Calibration configuration for thrust and nose gear load.

Typical time histories, illustrating the variation of the load on the nose gear and the nose gear extension during the static QSRA jump strut operation, are presented in figure 13.

The performance of the system measured during static tests at Wright Laboratory and Ames Research Center is summarized in figures 14 and 15 which present the effect of valve-open time at constant pressure, and the effect of reservoir pressure at constant valve-open time. In both of these figures, the time to reach the maximum load level, following the firing of the jump strut, is nearly constant and is independent of valve-open time (between 80 and 170 msec) and reservoir pressure. The time increment for the nose wheel to lift off the ground after activation, is seen to be greater at the lowest duration of the control valve-opening (from the Wright Lab data), compared to higher valve-open times (fig. 13). However, within the range of valve-open times used during the QSRA flight tests (80 to 170 msec) the time for the nose wheel to lift off the ground is relatively constant, indicating that the jump strut performance is essentially independent of the duration of the opening of the control valve. In figure 15, while the maximum load is seen to increase with pressure (as previously noted), the time for the nose wheel to break contact with the ground decreases slightly as reservoir pressure is increased.

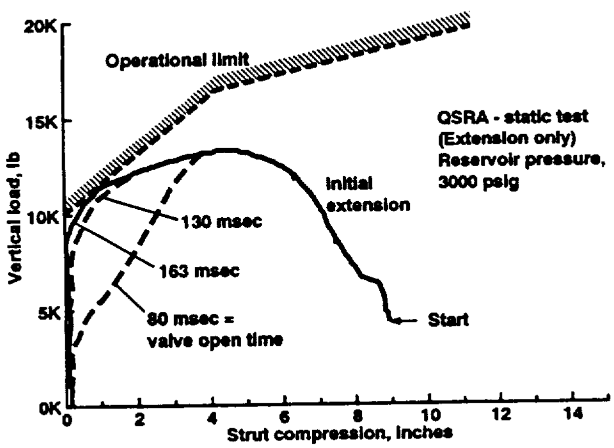


Figure 12. Effect of valve open time on QSRA strut load/stroke.

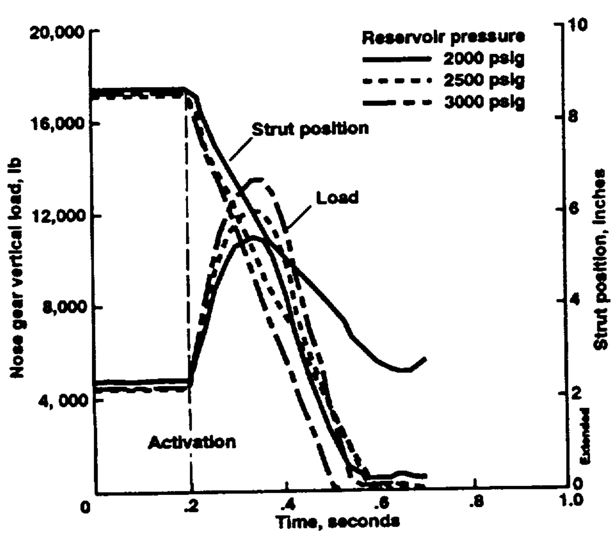


Figure 13. (a) Jump strut time history valve open time = 80 msec.

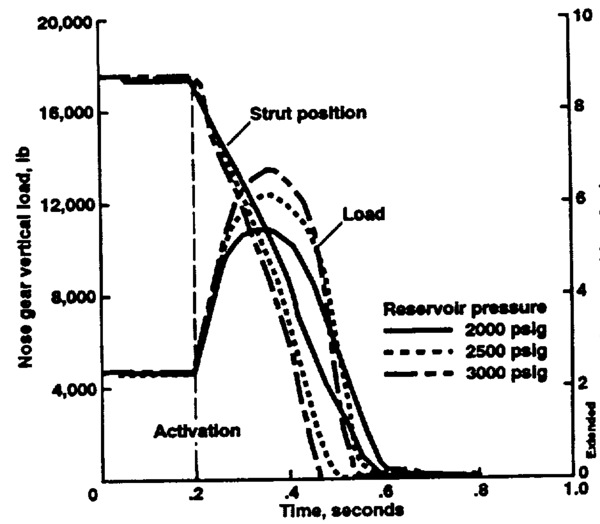


Figure 13. (b) Jump strut time history, valve open time = 170 msec.

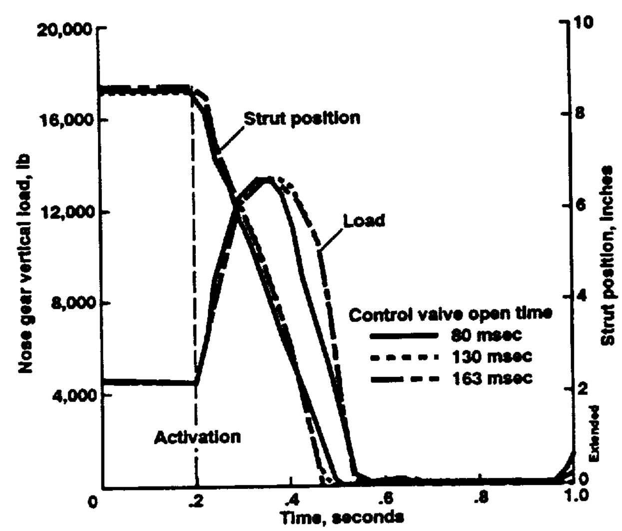


Figure 13. (c) Jump strut time history, pressure = 3000 psig.

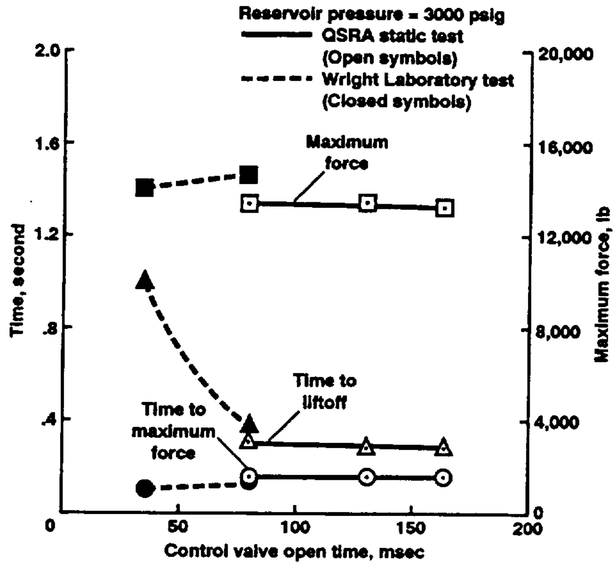


Figure 14. Jump strut performance, effect of control valve open time.

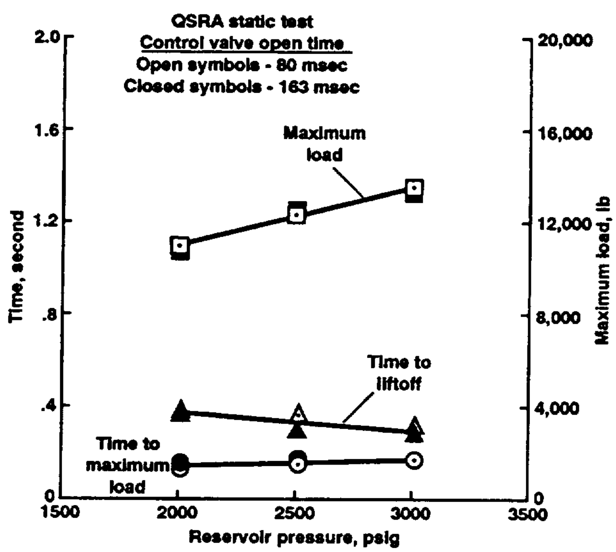


Figure 15. Jump strut performance, effect of reservoir pressure.

Jump Strut Flight Test

The objective of the flight test was to evaluate takeoff performance. Thrust to Weight (T/W) ratio values of 0.3, 0.35, 0.4, and 0.45; valve-open durations of 80, 130, and 170 msec; and pneumatic reservoir pressures of 2,000, 2,500, and 3,000 psig were investigated. Each point on the matrix required several takeoffs to determine the performance as a function of airspeed. Also, to establish baseline performance levels, takeoffs also had to be made at various thrust to weight ratios for a range of airspeeds without the jump strut.

For consistency during the data takeoffs, a series of preliminary flight tests were conducted to define the nominal aircraft configuration and pilot takeoff technique. It was determined that an initial elevator trim of five degrees nose down was a good compromise for elevator forces, takeoff speed, and nose loads. Zero force was used on the column during the takeoff roll which allowed the elevator to float up to near zero degrees during the acceleration. At the desired firing speed, as indicated by the head-up display, the elevator was snapped full aft simultaneously with firing the jump strut. Full up elevator was then held until 15° of pitch attitude was attained. This pitch attitude was then held until the aircraft was well airborne. This technique was repeatable and required a fairly low pilot workload. For all operations the double slotted flaps were set at 59° and the USB flaps were full up (0°). Also, to obtain the desired thrust to weight ratio, the selected takeoff rpm accounted for the ambient temperature and pressure. The initial nominal wing loading of 88 lb/ft^2 was achieved by operating with full, or nearly full wing tanks. The maximum thrust to weight ratio attainable for this configuration, due to engine thrust limitations, was approximately 0.4. Since the pneumatic reservoir had to be recharged for each jump takeoff, refueling was accomplished simultaneously to maintain the appropriate gross weight.

To ensure against accidental firing of the jump strut, the electronic control circuit was not armed until after brake release on the runway. This procedure eliminated the possibility of firing the jump strut with a high initial static load on the nose gear due to engine thrust, that could result in exceeding the allowable structural load limitations.

Flight Test Data

The takeoff ground roll distance was measured using a calibrated ground-based laser tracking system and a laser reflector mounted on the side of the fuselage. For this evaluation, the takeoff ground roll distance is measured from the point of brake release to the point of full extension of the main landing gear strut. Figure 16 illustrates the method used for determining ground roll takeoff distance. Lift off was considered to be the point at which the slope of the extending main gear strut reaches full extension. In addition to position on the runway, the true ground speed could be derived from the laser tracker data. The ground roll distance was then corrected for ambient wind using the method provided in reference 5, where the

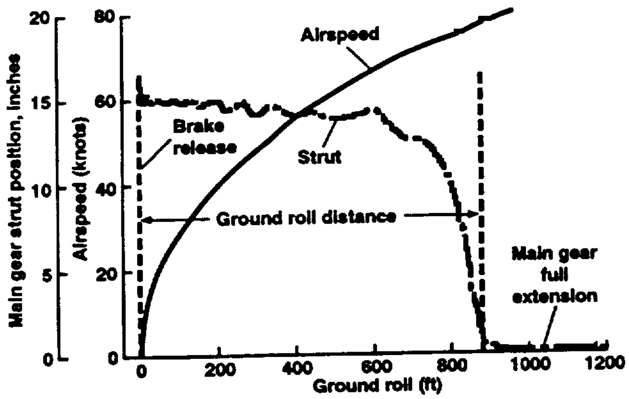


Figure 16. Determination of takeoff ground roll distance.

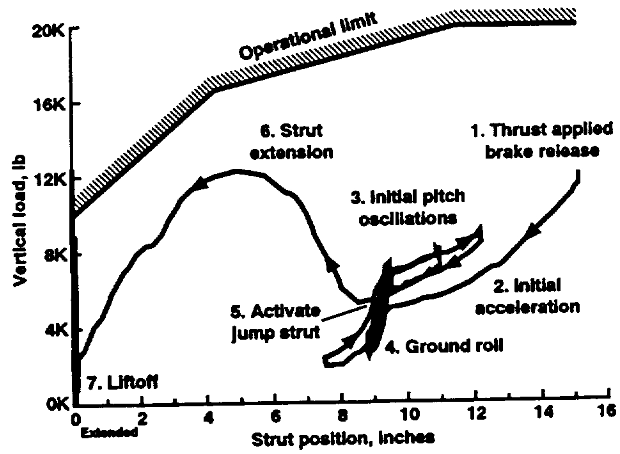


Figure 17. Typical operational load stroke curve.

magnitude of the runway wind component was obtained by taking the difference between the aircraft airspeed and the derived ground speed.

Because of the sensitivity of engine thrust to rpm setting and the ambient temperature and pressure, the actual T/W always differed slightly from the targeted value. The takeoff distances, therefore, were also corrected to the targeted T/W levels. To avoid large corrections to the measured data, takeoffs that resulted in excursions from the targeted thrust to weight ratio greater than 0.01 are not included in the plotted data.

Discussion of Results

A total of 72 takeoffs were completed. Of these takeoffs, 44 were jump strut assisted. Throughout the tests, the vertical nose gear loads, the nose gear cylinder rebound pressure and the nose gear axle acceleration remained within the allowable limits. A typical load/stroke history recorded during a jump strut takeoff is given in figure 17. The start point (1) shows the initial high load and resulting compression of the nose gear due to the application of thrust prior to brake release. As the aircraft accelerates from the static condition, the load on the nose gear reduces and the nose of the aircraft pitches up. This pitch-up produces a few noticeable pitch oscillations which damp out rapidly as the aircraft continues along the runway. During the ground roll, load variations without large strut movement are seen, probably due to runway surface roughness. At the desired speed, the jump strut is activated producing a rapid extension and an accompanying increase in load. The load diminishes as the extension continues until lift-off occurs.

Effect of Pneumatic Reservoir Pressure

Figure 18 shows the effect of pneumatic reservoir pressure on takeoff performance for a 0.4 thrust to weight ratio and a 170 msec valve-open duration. It should be noted that the fairing of the test data shown on this and subsequent figures represents the minimum measured distance, since any deviation from optimum conditions could contribute to a longer takeoff roll. The use of the jump strut reduces the minimum ground roll distance by about 110 ft compared to the unassisted takeoffs. However, no clear trend with respect to the effect of initial reservoir

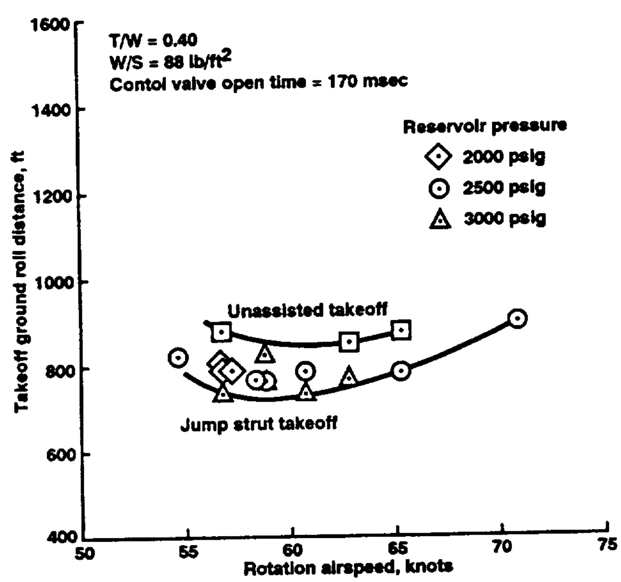


Figure 18. Unassisted and jump strut assisted takeoff performance with variation of reservoir pressure.

pressure on takeoff distance is detected. Although the maximum static nose gear load was earlier seen to increase with pressure, it appears that the dominant performance factors during the flight operations are the initial rate of load increase, and the time to achieve maximum load, illustrated in figure 13 which do not vary significantly for reservoir pressures between 2,000 to 3,000 psig.

Effect of Valve-Open Time

The effect of valve-open duration is illustrated in figure 19. For this comparison the any deviation from optimum conditions could contribute to a longer takeoff roll. The use of the jump strut reduces thrust to weight ratio is held at 0.4 and the initial reservoir pressure is 3,000 psig. As noted in the discussion of the effect of reservoir pressure, while the assisted takeoffs are approximately 110 ft shorter than the unassisted operations, no significant difference in performance due to valve-open time is detected.

Effect of Thrust to Weight Ratio

Figure 20(a) depicts the influence of thrust to weight ratio on ground roll distance for jump strut assisted takeoffs at a wing loading of 88 lb/ft^2. As expected, the lower T/W levels result in greater takeoff distances at all tested speeds as well as higher rotation airspeeds for the minimum distances. Figure 20(b) shows the unassisted takeoff performance. Minimum ground roll distances as a function of T/W for both the jump strut and unassisted takeoffs are given in figure 20(c). The reduction of ground

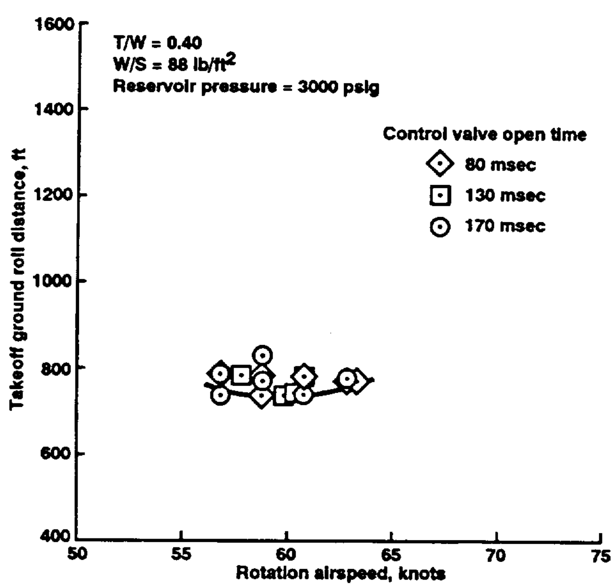


Figure 19. Jump strut assisted takeoff performance with variation of valve open time.

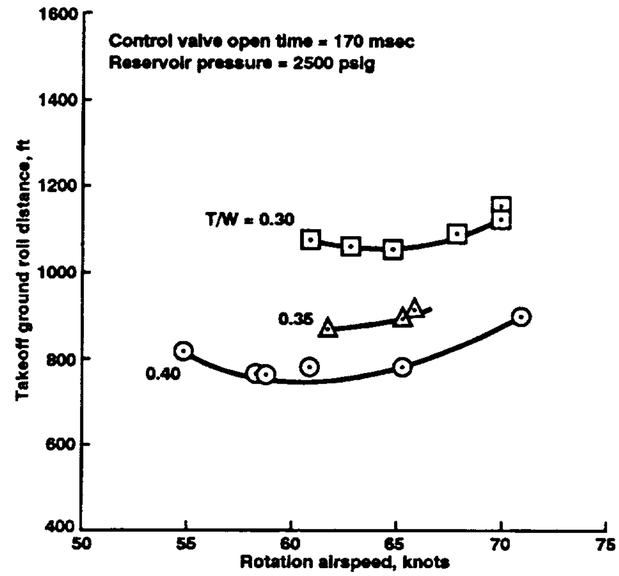


Figure 20. (a) Jump strut assisted takeoff performance with variation of thrust to weight ratio.

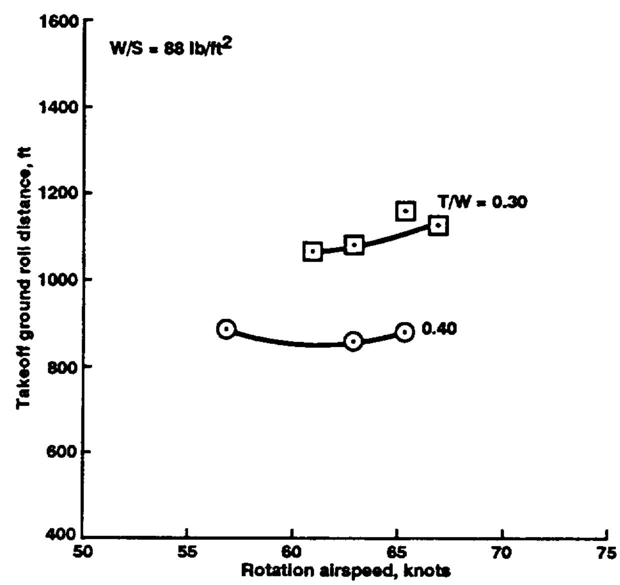


Figure 20. (b) Unassisted takeoff performance with variation of thrust to weight ratio.

roll distance obtained with the use of the jump strut is seen to diminish at the lower values of thrust to weight tested. At 0.4 T/W a 13% reduction of ground roll distance (fig 18) was established by the flight test data. These results validate the estimated improvements of 10–12% predicted in the reference 3 study.

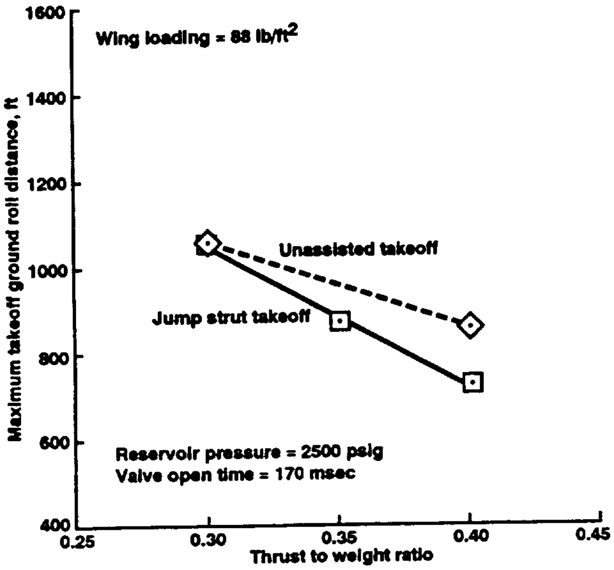


Figure 20. (c) Effect of thrust to weight ratio on minimum ground roll distance for jump strut assisted and unassisted takeoffs.

Jump Strut System Servicing and Operational Considerations

The jump strut system tested was light weight and was not complex, thereby making it representative of possible operational configurations. All elements operated reliably during the flight test program, although a failure of the magnetic-latching arm switch occurred during taxi tests after the completion of the flight activities. Servicing the pneumatic system required the development and application of safety procedures due to the handling of the high pressure gas. Servicing was conducted between test takeoffs, often with the engines running, and proved to be straight forward and safe and presented no special problems. The pneumatic system was charged with nitrogen during the initial tests and with dry air during the later flight tests. This change was made because of logistics problems associated with delivering the large quantity of pressurized nitrogen to the remote test site. No change in the operation of the jump strut system was observed. Post flight inspections of the nose gear assembly and associated airframe structure revealed no adverse effects as a result of the jump strut operations.

Repeatability of Jump Strut Ground Roll Distance

Considerable variations in the measured takeoff ground roll distance (up to 80 ft greater than the minimum distances) were observed when initial test conditions were repeated. Variables such as wind effects and pilot technique (such as the rate of the aft movement of the control column upon activating the jump strut and the attitude held for liftoff and climb-out) are suspected to contribute to these variations. Adequate data, however, was produced to determine the minimum takeoff ground roll distances (maximum performance) for both the jump strut assisted and unassisted takeoffs.

Recommendations

Preliminary testing indicated that piloting technique prior to and during the rotation is critical in consistently obtaining minimum ground roll distance. Because limited test opportunities prevented a comprehensive investigation of ground roll and rotation piloting techniques, it is recommended that this area be further explored.

Design innovations that improve the effectiveness and utilization of the jump strut, such as the use of a longer, single stage strut and the automatic inflight recharging of the pressure reservoir are additional areas for further development.

Conclusions

A pneumatic jump strut development program and flight test evaluation to determine the influence of a nose gear jump strut on takeoff ground roll distance was conducted using the NASA Quiet Short-Haul Research Aircraft. The operational experience with the jump strut and the test data support the following conclusions:

At a thrust to weight ratio of 0.4 and a wing loading of 88 lb/ft^2, the use of the jump strut reduced the takeoff ground roll distance by 110 ft, or 13% of the unassisted takeoff distance. This reduction of takeoff distance was found to diminish to a negligible amount when the thrust to weight ratio is decreased to 0.3.

Thrust to weight ratio more strongly influenced the takeoff ground roll distance for the jump strut assisted takeoff compared to the unassisted takeoff distance. For the nominal wing loading of 88 lb/ft^2, the assisted takeoff ground roll distance was reduced by approximately 320 ft by increasing the T/W from 0.3 to 0.4. The unassisted takeoff distance was reduced by only 210 ft for the same change in T/W.

Variations of reservoir pressure between 2,000 and 3,000 psig and variations of control valve-opening durations from 80 to 170 msec, did not have a significant effect on the ground roll distance for jump strut assisted takeoffs.

For fixed valve-opening times of 80 and 170 msec, at initial pressure values from 2,000 to 3,000 psig, the maximum load produced by the jump strut increased slightly with increasing pressure.

For initial pneumatic source pressure ranging from 2,000 to 3,000 psig, the maximum load and the time required to reach that load after activating the jump strut are essentially unaffected by the duration of the control valve-opening for values from 80 to 170 msec. The longer durations, however, maintained higher loads for a greater portion of the strut extension.

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13. ABSTRACT *(Maximum 200 words)*
A series of flight tests were conducted to evaluate the reduction of takeoff ground roll distance obtainable from a rapid extension of the nose gear strut. The NASA Quiet Short-haul Research Aircraft (QSRA) used for this investigation is a transport-size short takeoff and landing (STOL) research vehicle with a slightly swept wing that employs the upper surface blowing (USB) concept to attain the high lift levels required for its low-speed, short-field performance. Minor modifications to the conventional nose gear assembly and the addition of a high-pressure pneumatic system and a control system provided the extendable nose gear, or jump strut, capability. The limited flight test program explored the effects of thrust-to-weight ratio, wing loading, storage tank initial pressure, and control valve open time duration on the ground roll distance. The data show that a reduction of takeoff ground roll on the order of 10% was achieved with the use of the jump strut, as predicted. Takeoff performance with the jump strut was also found to be essentially independent of the pneumatic supply pressure and was only slightly affected by control valve open time within the range of the parameters examined.

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